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VI. An Account of several Experiments concerning  
the Running of Water in Pipes, as it is retarded  
by Friction and intermixed Air, some of which  
were made before the Royal Society on Thursday  
the 5th of May, 1726. With a Description of  
a new Machine, whereby Pipes may be clear'd of  
Air, as the Water runs along, without Stand-Pipes,  
or the help of any Hand. By the Rev. J. T  
Desaguliers, LL. D. F. R. S.

HAVING found by several Experiments in small, that thro' a long Pipe, Water wou'd not be discharg'd in the same Quantity by a great deal, as it wou'd be thro' a shorter of the same Bore, the Orifice being at the same Depth under the Surface of the Water in a Reservoir: I made an Experiment upon a Pipe above 1000 Yards in length, and of  $1\frac{1}{2}$  Inch Bore, at his Grace the Duke of Chandos's House at Cannons; and found that the Quantity of Water given was much less (I think  $\frac{1}{2}$  less) than it ought to have been according to Mons. Mariotte's Rules; and that something more than the Friction, on Account of the Length of the Pipe, had retarded the Water; which I found since to be Air confin'd in the eminent Parts of the Pipe. A full Account of this Experiment I publish'd in my Notes upon *Mariotte's Mouvement des Eaux*, in the English Translation, some Years ago.

Considering this Matter again lately, I made the following Experiment. Fig. 1. A is a Vessel containing a Cubic Foot in the Inside, and always kept full

by means of the Pipe *B* running from a larger Vessel. *CD*, is a short Pipe of  $\frac{1}{4}$  of an Inch Bore, two Foot in length, opening into the Bottom of the Cistern *A*, and whose Orifice *D* is always 10 Inches below the Bottom of *A*.

*OGEEHF*, is another Pipe of the same Bore, whose Orifice *F* is likewise 10 Inches below the Bottom of *A*. This Pipe is 113 Yards long, lying along the Ground five Foot below *A*, except the depending Part *OG*, and the ascending Part *HF*.

When *F* is stopped, and (*A* being kept full) the Water runs out at *D*, the Quantity of Water given is 19 Times more than when *D* is stopp'd, and the Water runs out at *F*.

The Air confin'd in several Parts of the long Pipe, is the chief Reason of this Difference.

In order to get rid of the Air, which lodging in the Pipe, contracts its Bore, and thereby lessens the Quantity of Water, which is to be deliver'd at the Issue, I made several Experiments to find whereabouts the Air does lodge, the more easily to let it out; one of which was as follows.

I took a Glass Pipe as *AB* (Fig. 2.) of about one Inch in Diameter, 12 Foot in length from *P* to *P*; only the Parts *AP* and *PB* at the other End, were of Lead. Then pouring in Water at *A*, till it came up to *B* (stopping the End *G*) the Air lodg'd in the eminent Parts of the Pipe at the Places mark'd *CC*, *DD*, and *EE*: But when the Water was suffer'd to go out at *G*, the Air came forward towards *G*, and took up the Spaces *cc*, *dd*, and *ee*, contracting the Bore of the Pipe as before, but stood forwarder in the Pipe, so that it generally happen'd that the Space of Air began upon the upper part of the Eminence of the Pipe.

*N.B.* The Glass Pipe may be made of several Pieces join'd to each other, and to the Leaden Pipes

and Funnels, by Brass Ferrils and Elbows, turning in all manner of Angles. These are not represented here.

If the Velocity of the Water is very great, the Air will go even beyond the Eminence of the Pipe.

To let out the Air from the Conduct Pipes, which obstructs the Running of the Water, I recommend the Experiments which I made, and the Apparatus which I applied to a Wooden Conduct Pipe of nine Inches Bore, which runs a Mile and an half from the Water Engine at *York-Buildings* to a Reservoir near *Cavendish-square*; the Surface of the Water in the Cistern at the Water-house being sometimes 15, and sometimes 20 Foot above the Issue at the Reservoir.

Upon a Part of the Pipe, such as *AB* (Fig 3.) I fix'd a Leaden Pipe *DF* of 2 Inches in the Bore, by means of 3 Ferrels, or short Communication-Pipes; the first at *D*, just beyond the Beginning of the Space *CC*, that us'd to be fill'd with Air in the running of the Water, the Second in the Middle of the Leaden Pipe, and the Third at the End of it; the Length of the Pipe itself being from 12 to 24 Feet, according to the Steepness of the Descent, the shortest Pipe being sufficient where the Descent is very quick. From the Middle of the Leaden Pipe above-mention'd (call'd a Rider from its being laid along on the Main or Conduct Pipe) there goes another Leaden Pipe as *EH*, of the same Diameter, rising all the Way very gently from *E* to the Cock *H*, and so on to *I*; because, if there was the least Descent, Water wou'd lodge in it.

Now, when the Water runs from *A* to *B*, the first Ferril *D* will catch the Air as it runs, so as to let it out at *I*, if the Cock *H* be open, sometimes without going to *G* or to *C*. But if the Cock had not been open'd, till the Water had pass'd thro' the Part *AB* of the Pipe, the Air wou'd lodge in the Space *CC*, and be

discharg'd upon the opening of the Cock. After the Cock has been shut, when no more Air comes, and Water succeeds, after soire time, Air will extricate it self out of the Water and come up to *CC*; or if it comes from the Parts of the Pipe towards *B*, it will rise contrary to the Current of the Water quite up to *C*, and so go out at the Pipe *EH*, when the Cock is open'd again.

As after the first Discharge of the Air, it cannot be known when more Air is g<sup>t</sup> into the Pipe, unless by opening the Cock, which woud require one Man to attend each Cock constantly, and occasion a waste of Water at every turn of the Cock, unless when Air happens to be in the Pipe ; it was propos'd to contrive a Valve that shou'd open to let out the Air, and shut again when the Water came ; and an inverted Brass Clack or Valve shutting upwards, and falling down by its own Weight, with Cork fix'd to the Under-side of it to help it to rise when the Water came, was mention'd as fit for the Purpose by some of the Persons that I was talking with about it. But we rejected that Proposal; because, when such a Valve has been shut some time, if Air shou'd extricate itself from the Water, it wou'd be dense Air, whose Force being equal to that of a Pillar of Water 30, 60, 80 or more Feet in height, it wou'd keep the Valve shut as well as the Water did before, tho' the Air at first cou'd not shut the said Valve.

At last, after several Thoughts, we contriv'd a Machine which exactly answers the Purpose, and is very simple ; therefore it will be of general Use.

The Description of it is as follows.

In the fourth Figure *G* is a Section of the Main or Conduct Pipe, with Water up to *G*, and Air above it, *AB* being an horizontal Line touching the Top of the said Pipe : *EHI* is the Leaden Pipe describ'd above, and

andmark'd with the same Letters as in the third Figure, reaching from the Pipe in the Street to the Side of an House, or to the Side of one of the Posts that are set up to keep off Coaches from the Foot-way. The Machine is the Box *K* made of Cast-Iron, fix'd to the Lead-en Pipe at *I*, with a thin Door of Plate-Iron, moving on Hinges, and made to lock at *D*. This Box stands in the Street out of the way of Passengers, with its Bottom fix'd to a Plank in the Pavement, so as not to be damag'd by a small Shock or any chance Blow.

The severall Parts of the Machine are the following.

Figure 5; *NN* is an Iron Plate about an Inch thick, with 4 Holes at 1, 2, 3, 4, of about an Inch Diameter, quite thro' the Plate, to let thro' 4 Screws, such as *a*; *OO* is a Face, or flat Ring rais'd out of the whole Stuff, and prominent about  $\frac{1}{4}$  of an Inch, ground, or turn'd to a true Flat. 5. Is an Hole of about  $\frac{1}{2}$  Inch Diameter, to receive the Nose of a Cock, which is put thro' it, stopping with a Shoulder or Flaunch screw'd within the Circle *OO* by 4 other Screws mark'd with large Points round the Hole 5.

Fig. 6. *NN* is the same Plate seen Edge-wise.

*M* is the Air-Cock screw'd to the said Plate thro' the Flaunch of its Pipe at *m n*, having its Key 6, 10, fasten'd to a Rod of about  $\frac{1}{4}$  an Inch Diameter of the Figure 6, 7, 8, 10, having a Shank one Foot long, 8, 9 join'd to a Buoy or hollow Copper Ball *L*, which Ball, when the said Shank is in an horizontal Situation, keeps the Cock shut; but falling by its own Weight, when not sustain'd by the Water, opens the Cock by means of the Rod 8, 9, as may be seen in Figure 7, where the Plate *NN* is screw'd to the Box, and the prick'd Line *ML* shews the Surface of the Water coming into the Box thro' the great Cock and Lead-en Pipe *HI*, so as to make the Ball *L* float with its Shank in

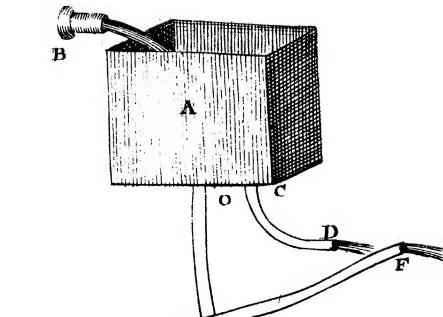
in the horizontal Situation 8, 9 ; but when more Air comes in to drive the Water down the Pipe *I*, the Buoy will fall to *I*, and its Shank coming down to 10, 11, will open the Air Cock *M*, and let out the Air (be its Density what it will) till it be all discharg'd, and the Water is again got up to *ML*, and has rais'd up the Buoy to *L*.

*NN* is the Fore-part of the Box with its Hole, to which the Plate of Fig. 5. is screw'd.

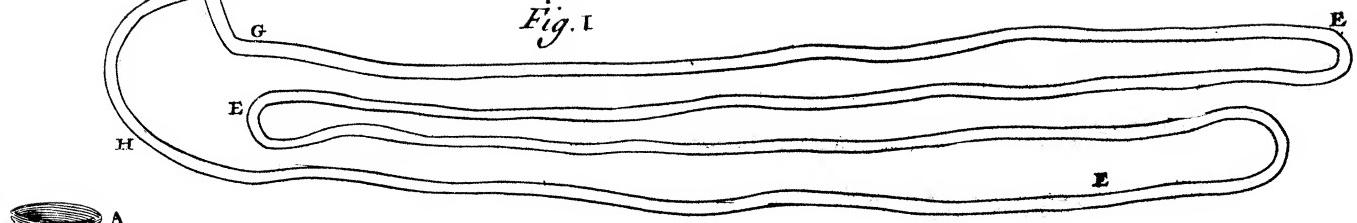
It is easily conceiv'd, that the Cock *H* must always be left open; that the End of the Pipe *I* is screw'd to an Hole in the Bottom of the Box by means of Screws at *rr*; that there are oil'd Leathers at the Heads of all the Screws, and likewise upon the Plate *NN*, to make the Face *OO* of Fig. 5. apply it self close to the Fore-part of the Box *K* (Fig. 8.) which has an Hole at *OO* to take in the Buoy and Cock of Figure 6, the Screws at 1, 2, 3, 4, which have their Heads within the Box, and their Nuts such as *b* (Fig. 5.) screw'd on, when the Plate *NN* is apply'd; and that the whole Box, thus fitted is made Air-tight.

*D* in Figure 4. and *DD* in Fig. 7. represent an Iron Door, to cover the Mouth of the Air-Cock from external Injury, and is punch'd full of Holes to let out the Air freely.

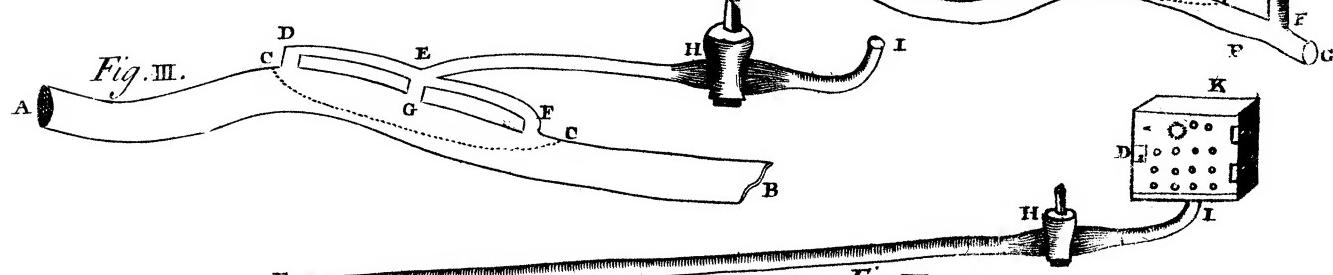
This Machine, which from its Make, we call'd a *Jack in a Box*, will be useful wherever Water is to be convey'd a great way in Pipes; and since I was not the sole Contriver of it, I ought in justice to those that join'd their Thoughts with me, to acquaint the Publick, that the Box is the joint Invention of Mr. *Richard Jones*, Mr. *James King*, Mr. *Thomas Newcomen*, Mr. *Joseph Hornblower*, his Operator, and my self.



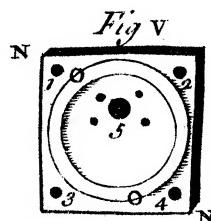
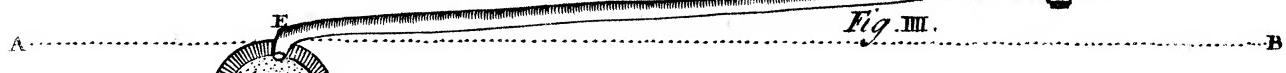
*Fig. I.*



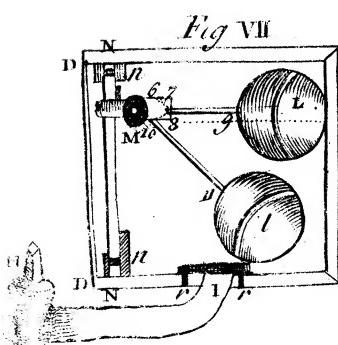
*Fig. II.*



*Fig. III.*



*Fig. VI.*



*Fig. VII.*



*Fig. VIII.*